Modulation-Demodulation Software Radio

Make your own IF software-defined radio (SDR) from an existing transceiver, and measure propagation phenomena with *MDSR* and *Scanning RF Seismograph* software.

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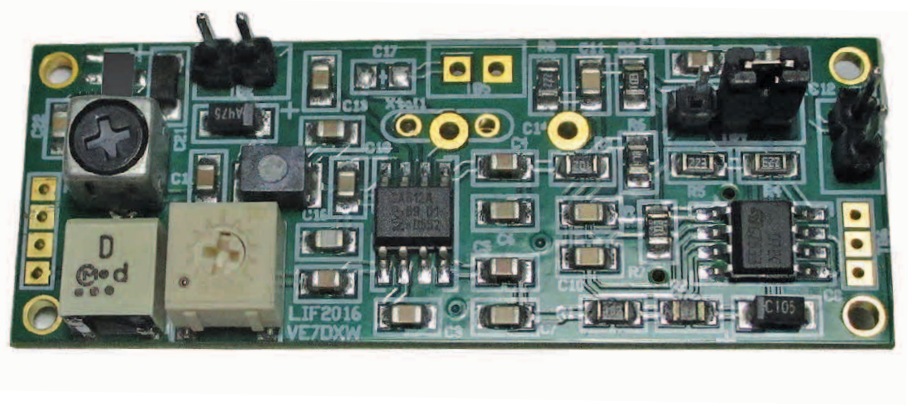

Today's analog receivers, even lower-end analog radios, have a dynamic range in excess of 80 dB, and are very affordable. The *Modulation-Demodulation Software Radio* (*MDSR*) system allows these older, perfectly functional radios to get a second lease on life. The low intermediate frequency (LIF) concept uses the 455 kHz IF, and downconverts it to 12 kHz, where it can be processed by a sound card. Once the signal is digitized, the digital signal processor (DSP) engine of the *MDSR* software can provide sharp IF filters, notch filters, and a whole range of SDR-like features that most analog rigs lack. The *MDSR* software also adds a real-time spectrum analyzer for fast tuning and a remote control feature that is easy to use and to set up. At the cost of an LIF converter printed circuit board (PCB — see the lead photo), and the time spent to connect the transceiver and the computer together, the *MDSR* system out-performs many SDRs available on the market today. Combined with a 24-bit sound card, which has a dynamic range of about 120 dB, the receiver opens up a whole new world of reception. The BiLIF is a bi-directional version of the LIF board that permits SDR transmission as well as reception.[1]

Connectability

The MDSR system can be set up to use two sound cards: One high-end 24-bit card to do the IF demodulation, and a lower 16-bit onboard sound card for handling baseband digital communications software such as *WSPR*, *JT65*, and *JT9*. The *MDSR* setup is a free program. It also includes *Fldigi* with its extensive choice of digital modes. Programs in the *MDSR* suite include:

MDSR — provides the graphic user interface that controls the transceiver via the OmniRig CAT translator and the DSP engine for audio processing;

MDSR-SA — provides a fast spectrum analyzer, the OmniRig setup utility, and preset frequency banks;

PM Manager — the Profile Manger is a backup utility that also stores profiles for different setups, such as digital setup or analog setup. It can also be used to store profiles to control dif-

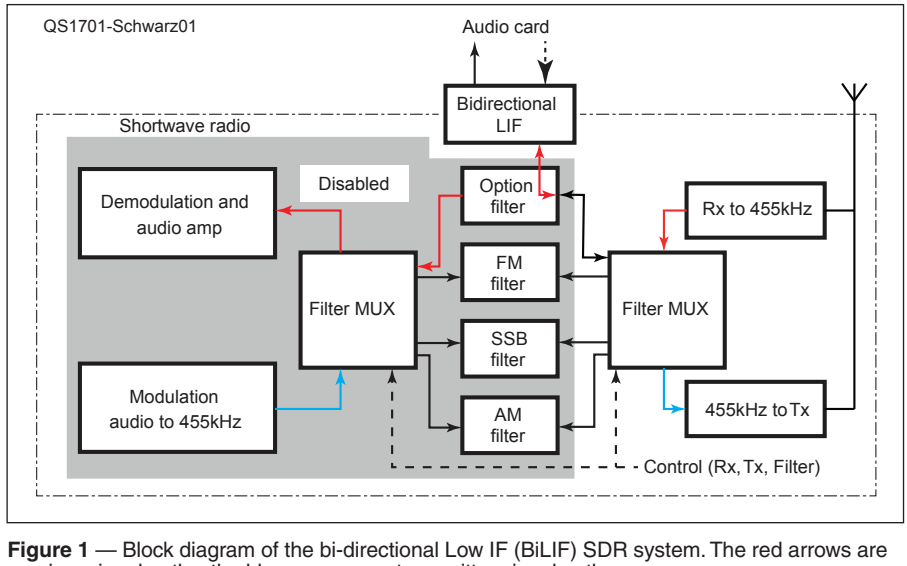

Figure 1 — Block diagram of the bi-directional Low IF (BiLIF) SDR system. The red arrows are receiver signal paths; the blue arrows are transmitter signal paths.

ferent transceivers. Once a profile is established, it can easily be recalled;

OmniRig — translates the CAT protocols of over 100 different radio makes and models so that *MDSR* can control them remotely;

Fldigi — developed by Dave Freese, W1HKJ, for modulating and de-modulating a large variety of digital baseband audio sound card modes;

Videolan VLC — for recording and playing audio, and streaming audio during remote operations;

Dream V1.1 — digital radio mondiale (DRM) demodulator for DRM shortwave radio reception;

Java SA — amplitude correcting real-time spectrum analyzer; uses band noise to calibrate the filter response curve for a flat spectral display without filter flanks;

Scanning RF Seismograph — for long-term receiver monitoring of up to six bands. It can be engaged to monitor passively while the user is not at the station.

Documentation and User Help

The *MDSR* development is extremely well documented and accessible to everybody. All the documentation is on the website, is free, and can be used for any Amateur Radio purpose.[2] Each program has its own easy-to-follow PDF reference help file. For issues that cannot be resolved by the user, *MDSR* maintains a Yahoo! user group and online searchable knowledge base.[3]

LIF (BiLIF) and MDSR Overview

The LIF and bi-directional LIF (BiLIF) concept utilizes an existing transceiver and extends the option filter port via a converter so that the signal can be processed by a sound card. Figure 1 shows the block diagram of the BiLIF. By processing the IF and not baseband audio, the *MDSR* software can perform many functions that most transceivers lack. A second connection via a computer control (CAT) cable is required to allow control of all functions of the host transceiver via the *MDSR* software. Thus, *MDSR* so completely controls the transceiver that it can be out of reach while operating.

The most important tools for tuning in weak signals are a real-time spectrum analyzer and on-screen IF-DSP filters that eliminate even the most severe interference.

The *MDSR* software enhances the radio without changing the way the connected radio works. Modifications to the transceiver are minimally invasive — in most cases reversible — allowing it to change from *MDSR* to standalone operation in minutes.

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Accomplishments in the Past Year

We developed and manufactured the LIF2016 PCB, improved the spectral amplitude correcting spectrum analyzer, and released updates as *Java SA V1.2*. We added a single-channel long-term noise level time graph, RF Seismograph, released as Java SA V1.3 (now *Java SA V1.4*, as of June 6, 2016). We implemented a scanner to monitor long-term noise levels on six different bands.

A presentation and the white papers are available at the MDSRadio Yahoo! user group. Previously published white papers are also available in the TAPR archives.

Development of the LIF2016 SMD PCB (Receive Only)

The original LIF used through-hole components, but is now available as a mostly SMD pre-assembled board, as this was the next step in making the *MDSR* development appeal to more Amateur Radio operators. The LIF2016 SMD PCB is shown in the lead photo. This robot-assembled design consists of two layers, and has more than 95% ground plane coverage. The downconverter hardware is small enough to fit into most transceivers internally. It is pin-compatible (see Figure 2) with the YF-122 crystal filter that fits into the option filter space of many Yaesu transceivers (see Figure 3). Modifying radios for *MDSR* is now very neat and fast.

The MDSR development is extremely well-documented and accessible to everybody.

The LIF2016 has all the components to allow for a LINE level input of a 16- or 24-bit sound card. There is also an

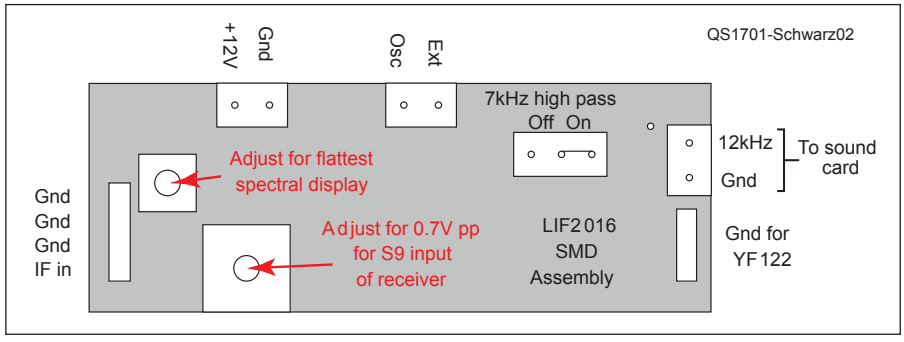

Figure 2 — Pinout and adjustment points of the LIF2016 SMD PCB. Compare with the lead photo.

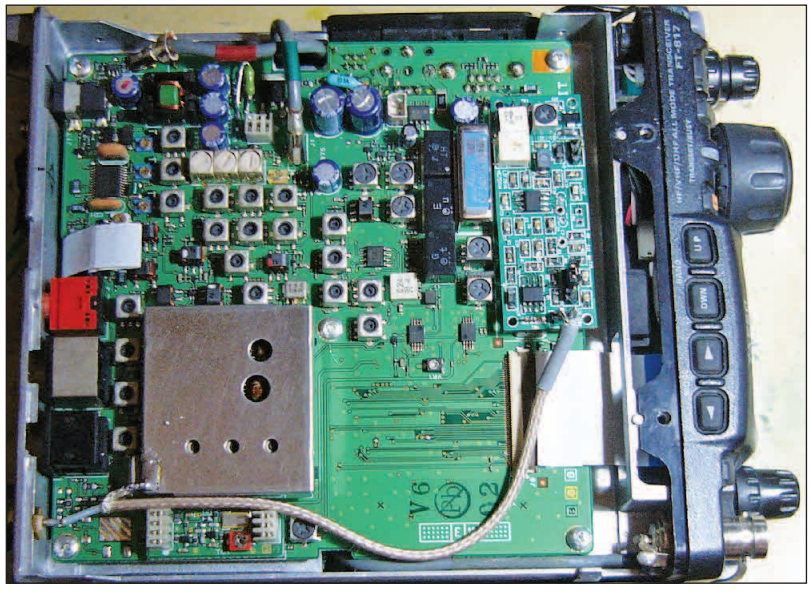

Figure 3 — LIF2016 SMD installed in a Yaesu FT-817 in place of a YF-122 option filter. The coax connects the 12 kHz IF output to a socket added to the rear panel.

additional 7 kHz high-pass filter that can be selected. It is set ON by default. Its purpose is to protect the sound card from low-frequency rumble that can overload the ADC circuit on the sound card.

Detailed documentation on the MDSR website presently covers installation into eight transceivers: the Icom IC-703, IC-7000, IC-756; the Yaesu FT-817, FT-857, FT-897, TF-950, and the Kenwood TS-2000. There are also instructions for a couple of receivers. There is further information in the support group for the IC-753, IC-746, IC-706mkII, FT-736, and TS-870. Many of the principles described are broadly applicable to other radios, and versions of the LIF are available to support 450/455 kHz and 9 MHz radios.

The LIF2016 makes the conversion of an analog radio very simple. All that is required is the installation of an LIF port as per instructions. The additional CAT control cable is controlled by *OmniRig*. *OmniRig* translates each CAT control command so they can be read by over 100 different transceivers, scanners, and receivers. This makes *MDSR* very versatile and flexible as a computer-controlled radio interface, with the additional benefits of digital signal processing via the LIF interface.

Your current radio can be upgraded to an SDR at a very low cost. The *MDSR* software is free. The LIF2016 is available for $50.[4] The LIF and the BiLIF are also available online on the MDSR website.

The RF Seismograph

The origin of this idea has several starting points. I used to have a weather station that was connected to the Weather Underground.[5] This is a brilliant concept that uses private weather stations linked via the Internet to display weather readings from all over the world. This concept is efficient, accessible to everyone, and it is free.

The solar flux graph that is shared over the Internet is also a neat way to monitor propagation. Unfortunately, there is not a lot of variation throughout the world when we correct the intensity depending on radiation angle. It is a bit like taking the average temperature of the planet and then stating, "It is 4°C in Florida." As a matter of fact, it is 4°C everywhere else, too.

The D-Region Absorption Prediction is another interesting model. It takes the amount of the solar flux and the angle of radiation into account. It is a negative indicator that shows which areas and bands cannot be reached during high solar activity. This model makes the assumption that the D-layer is uniform. It also neglects the fact that when solar radiation hits the D-layer at a shallow angle (sunrise and sunset), the energy exchange into the D-layer is stronger.

There are a large number of indices that can help to determine where an HF signal is supposed to end up and why it goes there. Most of them are based on solar activity. But where does the propagation come from in the absence of the Sun, low solar flux, or during a solar eclipse? What other phenomena can excite the D-layer and provide impressive DX coverage for shortwave bands?

There is always propagation, but it changes, and if someone says, "The conditions are terrible," they should actually say, "The bands have shifted. I wonder which ones are open now?"

Eliminating Local Noise Sources

The first task of setting up an RF propagation monitor is measuring noise in the environment that surrounds the station. By monitoring the time noise occurs and vanishes, one can pinpoint the location of offending units.[6] One big contributor of RF noise is the flat-screen TV. Figure 4 shows the interference caused by a particular TV at the author's location. The remedy is an ac RF-line filter and choke cores on the antenna input.

Other noise sources include fluorescent lighting, poorly-designed LED lamps, switch-mode power supplies in general — particularly cheap phone chargers — and electric motors. Electric motors can be cleaned up by putting an RF line filter in series with the ac power cord. But there are many

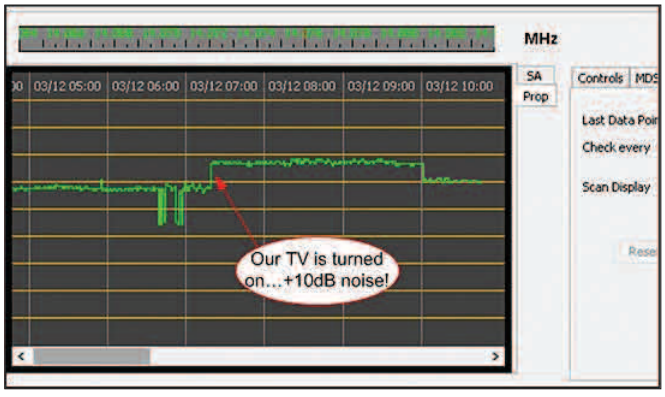

Figure 4 — Turning on your TV can lead to a significant increase in local noise.

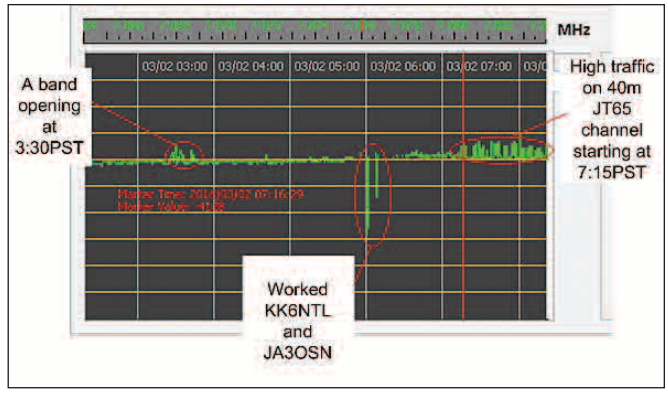

Figure 6 — An example of grayline propagation.

manmade noise sources that are very hard to get rid of. However, by doing this initial work, one can improve DX reception dramatically. Lowering the noise floor is the best antenna upgrade, because noise hides weak signals.

The Single-Channel RF Seismograph Confirms the Standard Model

X-ray solar flux hits the ionosphere and causes vibrations in the D-layer. These changes can be measured and monitored with the single-channel RF Seismograph. As a matter of fact, the solar flux graph on the National Oceanic and Atmospheric Administration (NOAA) website corroborates the measurement and the time.

But here the similarities end. Whereas the solar flux indicates a sharp spike, the local measurement is quite different. Because, for example, the local time is 7 AM on April 14, the Sun is very low in the sky. The radiation hits the D-layer at a very shallow angle. This lengthens the path and the time the radiation energy has to excite the local D-layer. More energy is transferred into the ionosphere. In Figure 5, at 6:50 AM the noise level goes up, spikes, and after 20 minutes, drops to a level still higher than the noise level before. It stays there for about an hour, drops abruptly again just above the regular noise level, and then stays there for another hour. There is another short spike, and then the noise level returns to normal.

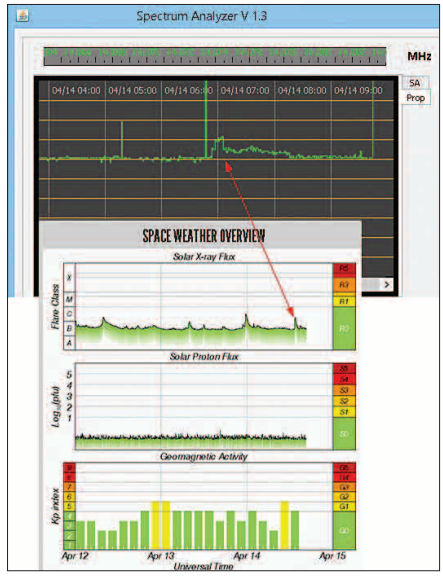

Figure 5 — A dropout on 20 meters caused by a coronal mass ejection. The NOAA graph shows UTC, and the Seismograph displays DST.

Follow the Grayline

A good strategy for finding propagation is following the grayline between day and night. This means operating DX during the morning and early evening hours. This works especially well on 40 and 20 meters — making worldwide contacts is not unusual. Figure 6 shows exactly that behavior. At about 4:30 AM local time, the band begins to open and stations from the far east and Australia start to come in. At 6:30 AM, the JT65 frequency is packed with DX stations. At 7:15 AM, the rest of the continent wakes up and the frequency is jammed with North American stations.

Propagation When the Sun "Flatlines"

This solar cycle has been very unusual. Even before the peak in 2014 – 2015, we saw a long period of very low solar flux. The Sun finally got active, but only for about a year, and has now flat-lined again! These are frustrating times for a ham radio operator — or are they? If X-ray flux is the only contributor to propagation, right now the bands should be dead. But they aren't, so what exactly is happening?

Bands still open up, but at different times and in unexpected ways. We have to re-learn how propagation redistributes RF energy, and change our operating times and methods accordingly.

In order to do this, we need a receiver that monitors the local RF conditions continuously, like a weather station that monitors air pressure and temperature, or a "seismograph" that records RF signals instead of tremors. It needs to do this over a very long time (more than 6 hours), and it must scan all frequencies of interest. This is where the *Scanning RF Seismograph* comes in.

Changing Habits

We must change our operating setup and procedures to more successfully

find RF propagation. We must also harden the antenna system against lighting and static discharges, and the operator needs to be comfortable leaving the station running and connected to the antenna at all times, even when absent from the station. Because we cannot predict the time when an event will occur, we must monitor at all times.

The *Scanning RF Seismograph Spectrum Analyzer V1.4*

Why use a Scanning RF Seismograph? Noise sources do not create noise that is evenly distributed through the radio spectrum. Neither do radio operators stick to just one frequency or band. With the six-channel scanner and RF level recorder, it is possible to record six different frequencies of interest. This is almost like having six radios receiving at one time. It will do that even while the operator is busy with other chores.

Java Spectrum Analyzer and *Scanning RF Seismograph V1.4*

The *Scanning RF Seismograph* is the latest release in the development program of the MDSR group. The main screen is shown in Figure 7. The computer interface separates the scanner setup from the display. All the functionality of the amplitude-correcting spectrum analyzer is still there, but hidden in this window display. For more details on how to set this program up and how to install it on the computer, go to the MDSR website. Also consult the included PDF help document. You may also find it useful to join the MDSRadio Yahoo! user group and post a message.

Using the *Scanning RF Seismograph*, or "How to Find Propagation"

Setting up the *Scanning RF Seismograph* is very simple, because it offers easy-to-use presets for the frequencies most amateurs will want to monitor, especially if the operator is using digital modes or merely wishes to observe

Figure 7 — Main window of the Java spectrum analyzer V1.4.

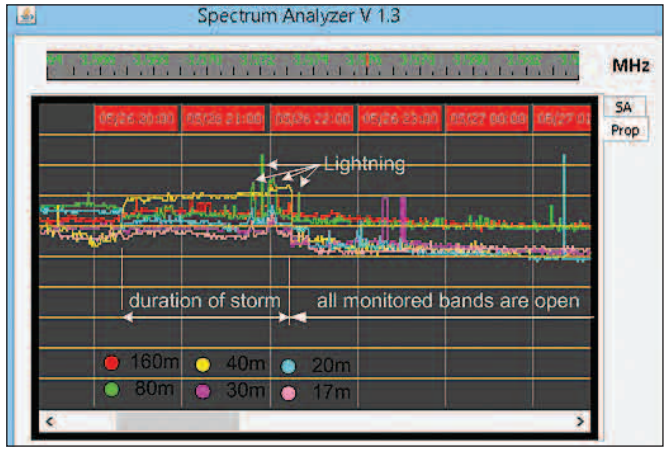

Figure 8 — Lightning detected by an earlier version of the Java spectrum analyzer.

standard transmissions such as WWV. Once the frequencies are set, pressing START SCAN launches the scanner and the recorder. The scanner is designed to run indefinitely, but also has a PAUSE/RES button so that the scan can be stopped and later resumed if the operator decides to use the transceiver for TX/RX operations.

Interesting Finds Using *Scanning RF Seismograph*

All the events recorded for this article were recorded during the standard operation of the station. Any antenna can be used to monitor RF conditions. My station uses a Hy-Gain 18HTJR omnidirectional multiband antenna.

Warning: Leaving the station connected during a thunderstorm without proper lightning protection can be hazardous to your life and property. It is not safe to operate any equipment connected to an antenna while a thunderstorm is within 10 miles (16 kilometers)!

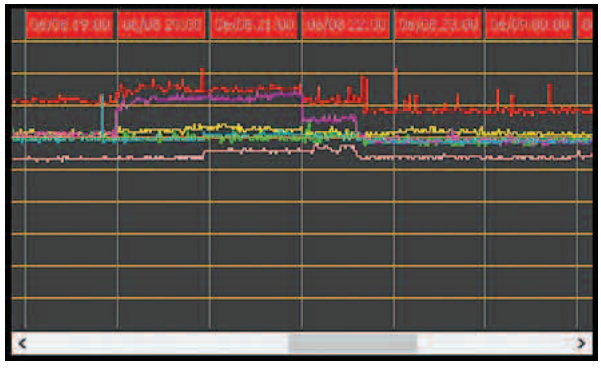

Figure 9 — Ten-meter propagation caused by airglow.

Figure 11 — Meteor scatter propagation seen on several bands.

Measuring the effects of a passing thunderstorm

Early evening on May 26, 2016, the Greater Vancouver area was treated to a rare thunderstorm. The MDSR team got lucky and the *RF Seismograph* was running automatically and unattended. Figure 8 shows the lightning spikes clearly detected on several bands.

The buildup of energy in the troposphere was visible at least 2 hours before the storm hit — shown left of the "duration of the storm" marker. During the 2-hour storm, the noise level of the 40-meter band jumped way up. In this particular storm, the lightning passed last, mostly seen in the green spikes (80 meters). Just after 2200, a big lightning strike made even the 17-meter band jump. At 2215, the noise of the 40-meter band dropped almost immediately even though the storm was just a few miles away. Then something happened that was rather unexpected — stations from all over the world were heard on all the monitored bands!

Can thunderstorms affect the D-layer? There are several explanations on how this is possible. My favorite theory is that the sprite discharge on top of the storm causes the ionosphere to ionize.

10-meter propagation caused by "nightglow"

Nightglow (also known as "airglow") is a phenomenon that causes a green glow in a dark, cloudless sky.[7] It looks similar to the soft green Aurora Borealis, but is more uniform and lacks the streaming nature of auroras. Nightglow is caused by atoms that recombine after being photo-ionized by UV radiation from the Sun during the day. Nightglow is mostly visible during the summer months around the solstice.

The pink (bottom) graph line in Figure 9 represents the 10-meter noise level. Just before 2100, the band noise increased slightly. After 2200, the band opened to allow 30 minutes of band activity. Also interesting is the effect on the noise level on 80 meters (red, top) and 20 meters (purple, second from top). During the time of the 10-meter opening, there were reports of strong nightglow sightings in Texas. The solar flux reading for this particular day was 92, and the geomagnetic activity was very low.

We have also run the *RF Seismograph* on 6 meters, but due to the lack of a good antenna, we have abandoned the attempt. With the right antenna though, the *RF Seismograph* would be ideal to monitor the 6-meter band.

Radio emissions from clouds (St. Elmo's fire)

Radio emissions from clouds are created when atmospheric conditions cause clouds to rise, or clouds are pushed up mountain slopes and start to ionize. This can create a lot of local RF noise, even before actual visual ef-

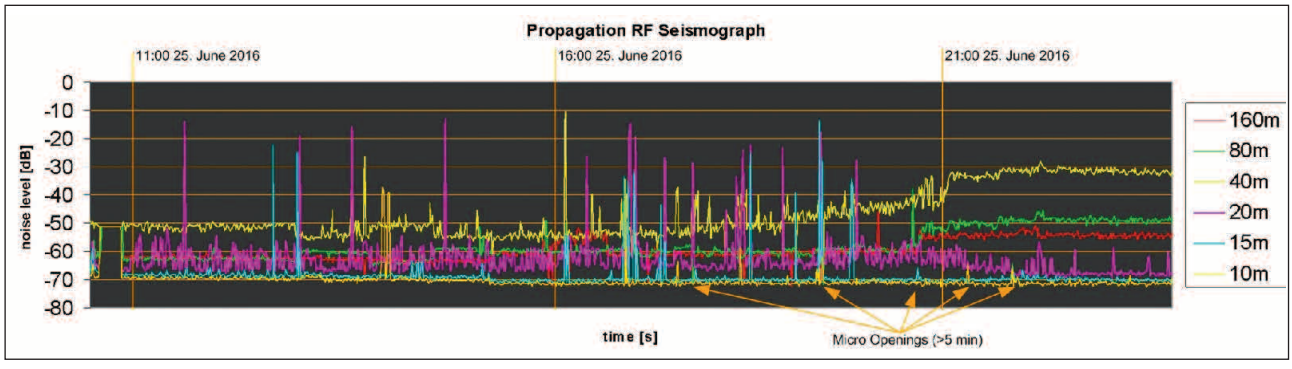

Figure 10 — Propagation measurement on Field Day 2016.

fects are observed.[8] The noise covers up signals with strong wideband noise, much like fog reduces visibility.

Figure 10 shows a recreation of data collected on June 25, 2016 — day one of Field Day operations at our local club, the North Shore ARC. The site is situated at a 2,500-foot (800-meter) elevation on the steep south-facing slope of the North Shore Mountains. The 40-, 20-, and 15-meter bands were open during the day. The morning was clear, then clouds began to move in during the afternoon. The yellow graph shows the 40-meter band noise starting to rise at around 5 PM. At 9 PM, the noise on 40 meters tops out at +20 dB above the morning starting level. Eighty and 160 meters stay constant for most of the day, then rise sharply just before 9 PM. After 10 PM, all bands are dead because of cloud radio emissions.

The data initially looked mysterious, especially because the main *RF Seismograph*, which was also running at a 400-foot (140-meter) elevation 10 miles (15 kilometers) away, did not record the noise increase. We posted the data to the MDSRadio Yahoo! user group and asked if anyone could explain the high noise level. Donn Hilton, VA7DH, reported the same mysterious noise in certain weather conditions on the west coast of Vancouver Island and linked it to charging and discharging water droplets. Peter Martinez, G3PLX, identified the noise as St. Elmo's fire.

Given the geographic location of the Field Day site and the weather conditions, this seems the only logical explanation. There was never a drop of rain and the wind was not strong. There was never any sign of a thunderhead or lightning, just clouds rising gently over the North Shore Mountains.

Propagation caused by meteor scatter

Most meteors are usually very small, and their ion trails get lost in all the other events during the day. At night, when the bands are quiet, a meteorite trail can cause some propagation.

This particular event, shown in Figure 11, happened at 2:40 AM local time. It starts out by increasing propagation on 40 and 30 meters. As the propagation drops after about 5 minutes, the noise level of the remaining bands also spikes for another 5 minutes.

Now that we know what a meteorite looks like on the *RF Seismograph*, we will spot more, even during the day.

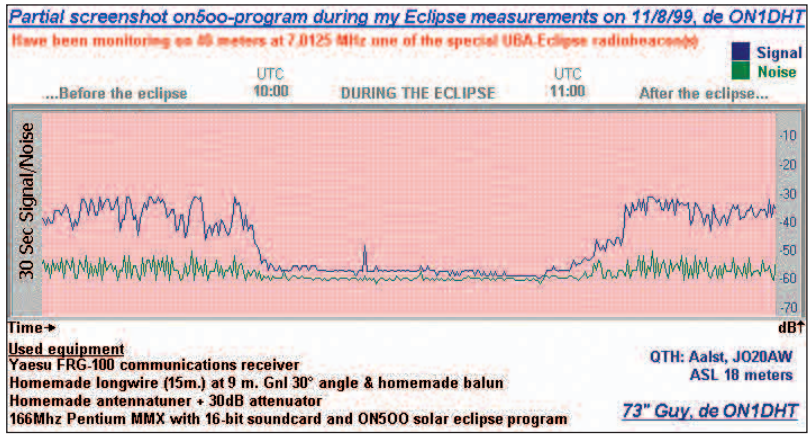

Figure 12 — 1999 eclipse measurements by Guy, ON6MU (then ON1DHT). [Guy Roels, ON6MU, image]

Figure 13 — Path of the center of the August 21, 2017 eclipse across the US. [Image from eEclipser courtesy of Xavier Jubier, at **tinyurl.com/2uvuud**]

Monitoring a Solar Eclipse (August 21, 2017)

This story begins in Belgium on August 11, 1999, when Guy Roels, ON6MU (ON1DHT at that time), was watching and recording the total solar eclipse on his computer using an audio card and a converter on his Yaesu FRG-100 receiver, very similar to the one we are using today. Figure 12 shows some of his results. The big difference today is that we can use the LIF2016 and a universal CAT interface to connect the receiver to the computer. The *MDSR* software, together with the *Scanning RF Seismograph*, can monitor the changes on six different bands. The data can be saved in a data format that is compatible with *Excel*. The implementation of a file upload utility

will make it easy to share the collected data with scientific organizations such as NASA, NOAA, and the Dominion Radio Astrophysical Observatory (DRAO).

Coverage of the Total Solar Eclipse in North America on August 21, 2017

Figure 13 shows the totality map of the line of totality (complete eclipse) that will go across North America on August 21, 2017. In southern Alberta and British Columbia, the coverage of the Sun will still be over 90%.[9]

The event will start on the west coast of America at 1604 UTC (10:04 AM local time) and then work its way across the continent in a southeastern direction. It will exit the US on the coast of South Carolina, northeast of Charleston, at around 2010 UTC (4:10 PM local time). The total time of the eclipse from start to finish is about 2 hours and 30 minutes. Adding the time it takes the Sun to pass North America, the time of the total event could be more than 5 hours for RF propagation effects.

Monitoring the Solar Eclipse with the *Scanning RF Seismograph*

The current version of the software is fully capable of monitoring such an event and recording it. There will be additional functionality in the version planned for this event. The bands being monitored will have to be synchronized with all the users. In addition, local information, such as the grid square and the call sign, will have to be entered. If there are new scientific discoveries, the person who submits the data of the event will be credited with the discovery.

Summary

The development of the *RF Seismograph* and then the *Scanning RF Seismograph* was a very worthwhile undertaking. It gives us the opportunity to share propagation reports among many users and makes use of the transceivers that sit idle in an unoccupied shack. The BiLIF schematic and bill of materials are available on the *QST* in Depth web page.[10]

We were already developing the *RF Seismograph* when we found out that there would be a solar eclipse in North America in 2017. At this time, Guy Roels, ON6MU, also sent us the link and described what he and the amateurs in Europe (Belgium) were doing in 1999.

During the development, we were able to observe and confirm the standard model of propagation and the role the Sun plays in it. But we were also able to extend the propagation model by showing how different phenomena can create workable propagation even when the solar flux is low.

With the outreach program and our Yahoo! user group, we invite all amateurs to participate in the Solar Eclipse 2017 experiment and then to forward the recorded data to solar scientists.

Acknowledgments

Thanks to Guy Roels, ON6MU, for the continued support of the *MDSR-SA*, maintenance of the website, and the creation of MDSR setup files; and to Alex Shovkoplyas, VE3NEA, for the use of the OmniRig CAT interface, and to Adam Farson, VA7OJ, for the continued support of his test lab and as a sounding board for ideas. Thanks to Dr. Ken Tapping, currently working for DRAO — he is responsible for the solar flux monitor station in Penticton, British Columbia.

Special thanks to Phil Burk for providing the *JSyn FFT* sound interface free of charge for this project.

We also acknowledge NOAA for their great website and the solar monitoring tools, and the Internet for being such a great repository of information and explanations of even the most abstruse subjects.

Notes

[1]**users.skynet.be/myspace/mdsr**
[2]**https://groups.yahoo.com/neo/groups/mdsradio/info**
[3]**www.tapr.org/pdf/DCC2010-Bidirectional-LowFrequencyTransverter-VE7DXW.pdf**
[4]**users.skynet.be/myspace/mdsr/order.htm**
[5]**https://www.wunderground.com/**
[6]**rsgb.org/main/files/2012/11/EMC04-Final.pdf**
[7]**www.albany.edu/faculty/rgk/atm101/airglow.htm**
[8]J. Doyne Sartor, "Radio Emission from Clouds," J. Geophys. Res., Vol. 68, No. 18, Sept. 15, 1963, pp. 2156 – 2202.
[9]**https://en.wikipedia.org/wiki/Solar_eclipse_of_August_21,_2017**; see also **http://eclipse.gsfc.nasa.gov/SEgoogle/SEgoogle2001/SE2017Aug21Tgoogle.html**
[10]**www.arrl.org/qst-in-depth**

Photos courtesy of the author.

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For updates to this article, see the *QST* Feedback page at www.arrl.org/feedback.

Strays

US Virgin Islands Jubilee Project

On March 31, 1917, the United States presented a warrant for 25 million dollars in gold to Danish Minister Constatine Brun to purchase what would come to be known as the US Virgin Islands. Throughout 2017, the Skanderborg (Denmark) Amateur Radio Club will be celebrating the 100th anniversary of the sale with the special event call sign OZ100DVI and offering a commemorative QSL card. For more information see **oz100dvi.oz7skb.dk**.